Chapter 6: Measles

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I. Disease description

Measles is an acute viral illness caused by a virus in the family paramyxovirus, genus *Morbillivirus*. Measles is characterized by a prodrome of fever and malaise, cough, coryza, and conjunctivitis, followed by a maculopapular rash. Though usually a mild or moderately severe illness of childhood, measles can result in residual neurological impairment from encephalitis in approximately 5–10 cases per 10,000 and in death in approximately 1–3 cases per 1,000.

II. Background

Before the introduction of measles vaccine in 1963, there were more than one-half million cases of measles reported each year in the United States. Since then, measles incidence has decreased to a record low of 100 reported cases in 1998.[1]

In recent years, outbreaks of measles have been small (<50 cases) and have chiefly involved high school and college students who are unvaccinated or have received only one dose of measles vaccine.

III. Importance of rapid case identification

Prompt recognition of the disease is important because the spread of measles can be limited with early case identification.

IV. Importance of surveillance

The highly contagious measles virus is frequently imported into the United States by persons coming from other countries. Each imported measles case could start an outbreak, especially if under-vaccinated groups are exposed. Surveillance and prompt investigation of cases and contacts help in halting the spread of disease.

Information obtained through surveillance is also used to assess progress towards disease elimination goals. Surveillance data are used to characterize persons, groups, or areas in which additional efforts are required to reduce disease incidence.

V. Disease reduction goals

The United States has established the goal of eliminating the transmission of endemic measles strains.[2] Current surveillance data indicate this goal has been achieved. To prevent imported strains of measles virus from establishing indigenous chains of transmission, rapid detection of cases is necessary so that appropriate control measures can be quickly implemented. Current elimination

strategies emphasize 90% measles vaccination coverage among children by 2 years of age and assuring vaccination with a second dose of measles vaccine for all school and college students.

VI. Case definitions

The following case definition for measles has been approved by the Council of State and Territorial Epidemiologists (CSTE), and was published in May 1997 (Appendix 1).[3]

Clinical case definition

An illness characterized by all of the following:

- A generalized maculopapular* rash lasting $\geq$ 3 days
- A temperature $\geq$ 101°F (38.3°C)
- Cough, coryza, or conjunctivitis

Laboratory criteria for diagnosis

- Positive serologic test for measles immunoglobulin M (IgM) antibody, or
- Significant rise in measles antibody level by any standard serologic assay, or
- Isolation of measles virus from a clinical specimen

Case classification

Suspected: Febrile illness accompanied by generalized maculopapular rash

Probable: A case that meets the clinical case definition, has noncontributory or no serologic or virologic testing, and is not epidemiologically linked to a confirmed case

Confirmed: A case that is laboratory confirmed or that meets the clinical case definition and is epidemiologically linked to a confirmed case. A laboratory-confirmed case does not need to meet the clinical case definition.

Comment. Confirmed cases should be reported to the National Notifiable Diseases Surveillance System (NNDSS). All cases should be classified as:

- **International Importation.** An imported case has its source outside the country or state, rash onset occurs within 21 days after entering the country, and illness cannot be linked to local transmission.
- **Indigenous case.** Any case that cannot be proved to be imported

should be classified as indigenous. Indigenous cases are sub-classified as follows:

- *Epidemiologically linked to importation* - Cases that are linked in a chain of transmission to imported cases should be classified as indigenous cases with an epidemiologic link to importation.

- *Virologic evidence of importation* - Cases in a chain of transmission from which a virus is cultured that is not indigenous to the United State are classified as indigenous cases with virologic evidence of importation. It is essential to obtain specimens for virology from every sporadic case (or at least 5 specimens from large chains of transmission) to assure adequate virologic information. Often the virologic information is not available at the time of reporting and the sub-classification is determined later. Cases which are epidemiologically linked to importation and have virologic evidence of importation are sub-classified as epidemiologically linked.

- *Not importation-associated* - Indigenous cases which are not epidemiologically linked to importation and have no virologic evidence of importation are sub-classified as not importation-associated.

- **Out-of-state importation.** Although the basic classification divides cases in to international importations and indigenous cases, states may also choose to classify cases as out-of-state importations when a case is imported from another state in the United States. The possibility that a patient was exposed within his or her state of residence should be excluded; therefore, the patient either must have been out of state continuously for the entire period of possible exposure (at least 7-18 days before onset of rash) or have had one of the following types of exposure while out of state: a) face-to-face contact with a person who had either a probable or confirmed case, or b) attendance in the same institution as a person who had a case of measles (e.g., in a school, classroom, or day care center). Out-of-state importations are uncommon.

VII. Laboratory testing

Because measles is an extremely rare disease in the United States, clinical evidence is not sufficient to confirm a case of measles. Many clinicians have never seen case of measles and most patients who present with measles-like illness today do not have measles. Because measles is such a highly contagious disease with the potential for explosive spread following importation of the virus it is critical to rapidly identify the few measles cases that do occur. This is why it is so crucial to use laboratory diagnosis to confirm the few measles cases among the thousands of patients with suspected measles.

Because measles is so rare, even with the excellent laboratory tests available, there will be some false positive results. (The positive predictive value of a test [PPV] is the proportion of people with positive results who actually have the disease. The PPV decreases when the disease becomes rare.) We expect to have some false positive results and prefer to misclassify as measles a few cases which are not actually measles than to miss cases which are measles.

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To minimize the problem of false positive laboratory results, it is important to restrict case investigation and laboratory test to patients most likely to have measles, those with fever and generalized maculopapular rash. Testing for measles in patients with no rash, or no fever, or a vesicular rash, or a rash limited to the diaper area leads to false positive results.

Serologic testing

Serologic testing, most commonly by enzyme immunoassay (EIA), is widely available and is almost always diagnostic when done at the appropriate time. Generally, a previously susceptible person exposed to either vaccine or wild-type measles virus first mounts an IgM response and then an IgG response. The IgM response is transient (1–2 months) and the IgG response persists. Uninfected persons are IgM negative and will either be IgG negative or IgG positive depending upon their previous infection or vaccination histories (Table 1).

Tests for IgM antibody

Tests that are negative in the first 72 hours after rash onset should be repeated; serum should be obtained for repeat testing 72 hours after rash onset. IgM is detectable for at least 30 days after rash onset and frequently longer.

EIA tests for IgM antibody require only a single serum specimen and are diagnostic if positive. There are two formats for IgM tests. The first and most widely available is the indirect format; IgM tests based on the indirect format require a specific step to remove IgG antibodies. Problems with removal of IgG antibodies can lead to false-positive tests[4] or, less commonly, false-negative results. The second format, IgM capture, does not require the removal of IgG antibodies. One direct capture IgM EIA is commercially available.

CDC has developed a capture IgM test for measles and trained personnel from every state public health laboratory in September 1995. This is the preferred reference test for measles.

IgM capture tests for measles are often positive on the day of rash onset. However, in the first 72 hours after rash onset, up to 20% of tests for IgM may give false-negative results. Tests that are negative in the first 72 hours after rash onset should be repeated; serum should be obtained for repeat testing 72 hours after rash onset. IgM is detectable for at least 28 days after rash onset and frequently longer.[5]

Tests for IgG antibody

A variety of tests for IgG antibodies to measles are available and include EIA tests, hemagglutination inhibition, indirect fluorescent antibody tests, microneutralization, and plaque reduction neutralization. Complement fixation,

although widely used in the past, is no longer recommended.
IgG testing for laboratory confirmation of measles requires the demonstration of a four-fold or greater rise in the titer of antibody against measles. Two serum specimens are always required. The first specimen should be drawn as soon after rash onset as possible, at the latest within 7 days of rash onset. The second specimen should be drawn 14–30 days after the first sample. The tests for IgG antibody should be conducted on both acute and convalescent specimens at the same time. The same type of test should be used on both specimens. The specific criteria for documenting an increase in titer depend on the test. EIA values are not titers and increases in EIA values do not directly correspond to titer rises.

Because tests for IgG require two serum specimens and a confirmed diagnosis cannot be made until the second specimen is obtained, IgM tests are generally preferred.

Virus isolation

Although isolation of measles virus is not recommended as a method to diagnose measles, virus isolates are extremely important for molecular epidemiologic surveillance to help determine 1) the origin of the virus, 2) which viral strains are circulating in the United States, and 3) whether these viral strains have become endemic in the United States. Isolation of measles virus is technically difficult and is generally performed in research laboratories.

Specimens (urine, nasopharyngeal aspirates, heparinized blood, or throat swabs) for virus culture should be obtained from clinically suspected cases of measles.

Specimens (urine, nasopharyngeal aspirates, heparinized blood, or throat swabs) for virus culture obtained from clinically suspected cases of measles should be shipped to the state public health laboratory or CDC, at the direction of the state health department as soon as measles is confirmed . Specimens should be properly stored while awaiting case confirmation (Appendix 9). Clinical specimens for virus isolation should be collected at the same time as, and in addition to, samples taken for serologic testing. Because virus is more likely to be isolated when the specimens are collected within 3 days of rash onset, collection of specimens for virus isolation should not be delayed until laboratory confirmation is obtained. Clinical specimens should ideally be obtained within 7 days of rash onset, and should not be collected if the opportunity to collect a specimen is more than 10 days after rash onset.

For additional information on laboratory support for surveillance of vaccine-preventable diseases, see Chapter 19.

VIII. Reporting

Each state and territory has regulations and/or laws governing the reporting of diseases and conditions of public health importance (Appendix 2).[6] These regulations/laws list the diseases that are to be reported and describe those persons or groups who are responsible for reporting, such as health-care providers, hospitals, laboratories, schools, day care facilities, and other institutions. Contact your local or state health department for reporting requirements in your state.

Reporting to CDC

Provisional reports of suspected measles should be promptly reported to the CDC by the state health department, via telephone at 404-639-8230 or e-mail (sbr1@cdc.gov). Case information should then also be reported by the state health department to the National Notifiable Diseases Surveillance System (NNDSS) through the National Electronic Telecommunications System for Surveillance (NETSS) within 14 days of the initial report to the state or local health department. Although only data from confirmed cases are published in the MMWR, states are encouraged to notify CDC of all suspected cases by phone as soon as possible.

Note: CDC, National Immunization Program (NIP), Epidemiology and Surveillance Division, publishes a weekly measles update that is distributed by mail, fax, or e-mail to all states. The update describes details of recent measles activity (sporadic cases and epidemics) by state. To receive the update call your state health department or send an e-mail request to CDC (sbr1@cdc.gov).

Information to collect

The following data are epidemiologically important and should be collected in the course of case investigation. Additional information also may be collected at the direction of the state health department.

- Demographic information

- Clinical details, including
  - — Date of onset of all symptoms and date of rash onset
  - — Rash duration and presentation
  - — Complications and hospitalization

- Laboratory information including
  - — Serologic test results
  - — Date of collection of specimen for virus isolation

- Case classification

- Vaccination status, including
  - — Number of doses of measles vaccine
  - — Date(s) of measles vaccination(s)

- Risk factors for disease, including
  - — Import status (indigenous, international import, or out-of-state import)
  - — Contact with a probable or confirmed case
  - — Contact with immigrants or travelers
  - — Travel history
  - — Setting (i.e., is case part of an outbreak or is it a sporadic case)

- Dates, including
  - — Date reported to health department

— Date of case investigation

IX. Vaccination

Measles vaccine is incorporated with mumps and rubella vaccine as a combined vaccine (MMR). The current ACIP recommendations for routine vaccination indicate a first dose at 12–15 months of age with a second dose at school entry (4–6 years).[7]

X. Enhancing surveillance

As measles incidence declines, additional effort may be required to ensure that appropriate and timely diagnosis of rash illnesses and reporting of suspected cases continues. In addition, the rapid investigation and reporting of all suspected cases and recording of vaccination history and import status for all cases will become increasingly important.

The activities listed below can improve the detection and reporting of measles cases and improve the comprehensiveness and quality of reporting. Additional guidelines for enhancing surveillance are given in Chapter 16, "Enhancing Surveillance."

Searching hospital and managed care records. Hospital and managed care administrative records should be searched yearly to evaluate the completeness of the reporting of patients with measles.

Mortality data are available through the vital records systems in all states. They may be available soon after deaths occur in states using electronic death certificates. Although no acute deaths from measles in the United States have been documented since 1992, each measles-associated death is important and warrants a full investigation. Mortality data should be reviewed each year to identify deaths that may be due to measles. Any previously unreported cases identified through this review should be reported.

Investigating contacts. Determining the source or chain of disease transmission, identifying all contacts (household, day care, and other close contacts), and following up with susceptible persons may reveal previously undiagnosed and unreported cases.

Active surveillance. Active surveillance for measles disease should be conducted during outbreaks. Local or state health departments should contact health providers in outbreak areas to inform them of the outbreak and request reporting of any suspected cases. These activities are especially important in large cities and in cities that have large numbers of international visitors.

Special projects. Special projects such as reviewing emergency department logs to identify rash illnesses that may have been unreported cases of measles may be used to evaluate surveillance sensitivity and completeness of reporting.[8]

Monitoring surveillance indicators. Regular monitoring of surveillance indicators, including time intervals between diagnosis and reporting and completeness of reporting, may identify specific areas of the surveillance and reporting system that need improvement.

1. The proportion of confirmed cases reported to the NNDSS with complete information.

2. The median interval between rash onset and notification of a public health authority, for confirmed cases.

3. The proportion of confirmed cases that are laboratory confirmed.

4. The number of cases that meet the clinical case definition, but are not confirmed.

5. The number of cases that meet the clinical case definition in which measles is ruled out by appropriate laboratory testing.

6. The number of chains of transmission that have an imported source.

7. The number of chains of transmission for which at least one clinical specimen for virus isolation was collected and submitted to CDC.

Another important indicator of the adequacy of the measles surveillance system is the level of investigative effort. This is measured as the number of suspected measles cases investigated and discarded for a particular area and may be expressed as a population rate. Even in the absence of measles, measles-like illnesses occur and should be investigated.[9] A program which reports no investigation suspected cases cannot be assumed to have adequate measles surveillance. For more information on surveillance indicators, see chapter 15.

XI. Case Investigation

All reports of suspected measles cases should be investigated immediately. The measles surveillance worksheet (Appendix 10) may be used as a guideline for collecting demographic and epidemiologic data during case investigation. Essential components of case investigation include:

Establish a diagnosis of measles (Figure)**.** Necessary clinical information must be obtained to establish whether or not a reported case meets the clinical case definition (see "Case definitions"). If the case was reported within 3 days of onset of rash, there must be appropriate follow-up to establish rash of at least 3 days' duration.

Laboratory confirmation is essential for all outbreaks and all isolated (sporadic) cases (those cases that are not part of a known outbreak). In an area of low measles incidence, most cases that meet the clinical case definition will not turn out to be measles.[9] Even in outbreaks, laboratory confirmation should be obtained on as many cases as possible. Once community awareness is

increased, many cases of febrile rash illness may be reported as suspected measles, and the magnitude of the outbreak may be exaggerated if these cases are included in the absence of laboratory confirmation. This is particularly important as the outbreak is ending; at that point, laboratory confirmation should be sought on all suspected cases.

The occurrence of measles-like illness in recently vaccinated persons can pose particular difficulties in the outbreak setting. Ten percent of recipients of measles-containing vaccine may develop fever and rash approximately one week after vaccination, and vaccination of susceptible persons results in production of IgM antibody that cannot be distinguished from that resulting from natural infection. A positive measles IgM positive test cannot be used to confirm the diagnosis of measles in persons with measles-like illness who received measles vaccine 6–45 days before onset of rash. A negative test would exclude the diagnosis. Persons with measles-like illness who received measles vaccine 6–45 days before onset of rash should be classified as confirmed cases of measles **only if** (1) they meet the clinical case definition, and (2) they are epidemiologically linked to a laboratory-confirmed case. For persons receiving vaccine 6–14 days prior to rash onset, specimens for viral isolation should be obtained in addition to serologic testing (see "Laboratory testing"); isolation of wild measles virus would allow confirmation of the case.

Case investigation and vaccination of susceptible household contacts should not be delayed pending the return of laboratory results.

Currently, very few of the suspected and probable cases investigated are confirmed as measles. Case investigation and vaccination of susceptible household contacts should not be delayed pending the return of laboratory results. Initial preparation for major control activities also may need to be started before the laboratory results are known. However, it is reasonable to delay major control activities, such as vaccinating an entire school, pending the return of laboratory results, which should be obtained as quickly as possible (within 24 hours).

Obtain accurate and complete immunization histories on all confirmed cases. Measles case investigations should include complete immunization histories that document all doses of measles-containing vaccine. All confirmed case-patients should then be classified as recipients of one valid dose of measles-containing vaccine (as MMR, measles-rubella, or measles vaccine), two valid doses, three valid doses, or no valid doses of vaccine. Doses are valid if given on or after the first birthday, with a minimum interval of 1 month between doses. Written records with dates of vaccine administration are the only acceptable evidence of vaccination.

Some case-patients or their care givers may have personal copies of immunization records available that include dates of administration; these are acceptable for reporting purposes. Usually immunization records must be sought from review of day care or school records (generally available for children attending licensed day care centers or kindergarten through high school), or from providers. Immunization registries, if available, can readily provide vaccination histories. In the absence of a registry, immunization records should be searched at providers' clinics or offices. As part of the initial case investigation, case-patients or their parents should be asked where **all** vaccines

were received, including the names of private physicians and out-of-town or out-of-state providers. Records at public health departments and health centers should be reviewed, and private physicians should be contacted and asked to review patient records for this information. With careful planning in an outbreak setting, it is possible to contact providers with a list of all case-patients reported to date on whom data are needed, and to call back at a prearranged time, rather than repeatedly contacting providers for records on different children.

Identify the source of infection. Efforts should be made to identify the source of infection for every confirmed case of measles. Case-patients or their caregivers should be asked about contact with other known cases. In outbreak settings, such histories can often be obtained. When no history of contact with a known case can be found, opportunities for exposure to unknown cases should be sought. Such exposures may occur in schools (especially high schools with foreign exchange students), during air travel, through other contact with foreign visitors, while visiting tourist locations (casinos, resorts, theme parks), or in health-care settings. Unless a history of exposure to a known case within 7–18 days prior to onset of rash in the case is confirmed, case-patients or their caregivers should be closely queried about all these possibilities.

Obtain specimens (urine or nasopharyngeal mucus) for virus isolation from all cases (or from at least some cases in each outbreak) at the time of the initial investigation; do not wait until serologic test results are received.

Assess potential for transmission and identify contacts. Transmission is particularly likely in households, schools, and other institutions (colleges, prisons, etc.), and in health-care settings. As part of the case investigation, the potential for further transmission should be assessed, and contacts of the case-patient during the infectious period (4 days before to 4 days after onset of rash) should be identified. In general, contacts that have not received two doses of measles-containing vaccine on or after the first birthday separated by at least 1 month are considered susceptible. These susceptible contacts are at risk for infection and further transmission to others and should be vaccinated as quickly as possible.

Obtain specimens for viral isolation. Efforts should be made to obtain specimens (urine or nasopharyngeal mucus) for virus isolation from all cases at the time of the initial investigation; do not wait until serologic test results are received (Appendix 9). These isolates are essential for tracking the epidemiology of measles in the United States, now that indigenous transmission of measles has been interrupted in this country.[1] By comparing isolates from new case-patients to other virus samples, the origin of particular virus types in this country can be tracked. For more information on obtaining and shipping these specimens, see “Laboratory testing.”

XII. Outbreak investigation

Although a complete description of activities to be undertaken in an investigation of a measles outbreak is beyond the scope of this manual, the following guidance may be useful to local health department personnel responsible for outbreak investigations.

Currently, very few of the suspected and probable cases investigated are confirmed as measles. Case investigation and vaccination of susceptible household contacts should not be delayed pending the return of laboratory results. Initial preparation for major control activities also may need to be started before the laboratory results are known. However, it is reasonable to delay major control activities, such as vaccinating an entire school, pending the return of laboratory results, which should be obtained as quickly as possible (within 24 hours).

Organizing for outbreak investigation. Because investigating an outbreak requires many person-days of work, often personnel are transferred to the activity from other responsibilities in the health department or other health departments, and may only be involved in outbreak investigation for a few days before they are replaced by someone else. This turnover in personnel will cause problems unless activities are organized so that the status of the investigation is documented at all times. Some practical suggestions for organizing this activity are as follows.

- Use a logbook (or large chalkboard) to record all suspected cases as they are received. The person who receives the initial telephone call should attempt to obtain the information needed to fill in the line listing (Table 2).

- Create a column in the logbook for actions needed for each suspected case ("draw blood," "call pediatrician for vaccination history," "notify contacts").

- Identify a team leader for case investigators so that at least one person knows about all the new cases called in that day and what still needs to be done. Daily briefings are a good way of keeping the whole staff informed of the status of the investigation.

- Keep the logbook in one well-defined location, preferably with folders with the case investigations of all the cases that have been reported. It is useful to have one stack of all confirmed cases, one stack of suspected/probable cases awaiting further investigation or lab results, and a separate stack of discarded cases. The latter are very useful for reassuring people who call the health department concerned that they have been exposed to measles.

- Establish protocols for control measures necessary for all likely situations (e.g., exposure in a day care, school, doctor's office,

  workplace, etc.) and clearly define who (e.g., local health officer, immunization program manager) will make the decision to proceed when a case investigator identifies a situation that might require major investments of health department resources (such as vaccinating a whole school). For guidelines on outbreak control, see below.

Track what information is collected and what still needs to be collected.

This is easily done by constructing a line listing of cases, which allows you to readily identify those data which are known, and which are unknown, and helps assure complete case investigation. A line listing can be maintained on a computer using database management or spreadsheet software, but often is most useful when filled in by hand on a form such as shown in the Table 2. Such a line listing can provide at any time a summary of the current outbreak and status of ongoing case investigations, and is an essential component of every outbreak investigation.

Identify the population affected by the outbreak. In the course of the outbreak investigation, every suspected case (whether reported through active or passive surveillance, or identified through contact investigation) should be investigated thoroughly, as described above. In very large outbreaks, it may not be possible to investigate each reported case thoroughly, but fortunately no very large outbreaks (>200 cases) have occurred in the United States since 1992.

Based on the findings of individual case investigations, the population affected by the outbreak should be characterized in terms of person (who is getting measles and how many case-patients have had zero, one, and two doses of measles vaccine?), place (where are the cases?), and time (when did it start and is it still going on?). (For more information on data analysis, see Chapter 17.) These are the essential elements that allow public health officials to identify the population at risk of infection (unvaccinated preschool-age children, high school students who have only received one dose of measles vaccine, persons who visited the emergency room of Hospital A on a certain day, etc.), determine where transmission is occurring (day care centers, high schools, health-care settings), and identify persons who are at potential risk of infection (other unvaccinated pre-school age children, students who attend other schools, etc.) In general, the most effective outbreak control efforts are those that are targeted based upon epidemiologic data, rather than those that are directed at the entire community. Neither susceptibility nor risk of exposure is uniformly distributed throughout the community, and resources available for outbreak control are always limited. Therefore, it is essential that data be used to determine the scope of the current outbreak and the potential for spread, and that interventions be based on those determinations.

In general, the most effective outbreak control efforts are those that are targeted based upon epidemiologic data, rather than those that are directed at the entire community.

Enhance surveillance for measles. Many of the activities outlined in the section on “Enhanced surveillance” are applicable in the outbreak setting. Previously unreported cases may be identified by reviewing emergency room logs or laboratory records. As part of outbreak response, active surveillance for measles should be established to assure timely reporting of suspected cases in the population known to be affected by the outbreak, as well as other segments of the community that may be at high risk of exposure or in whom vaccination coverage is known to be low. Hospital emergency rooms and physicians serving affected communities are usually recruited to participate in active surveillance. Active surveillance should be maintained until at least 1 month after the last confirmed case is reported.

XIII. Outbreak control

The primary strategy for control of measles outbreaks is achieving a high level of immunity in the population in which the outbreak is occurring. In practice, the population affected is usually rather narrowly defined (such as one or more schools); high immunity in the population is obtained by achieving high coverage with 2 doses of measles vaccine in the affected population. Persons who cannot readily provide documentation of measles immunity should be vaccinated or excluded from the setting (school, hospital, etc.). Only doses of vaccine with written documentation of the date of receipt should be accepted as valid. Verbal reports of vaccination without written documentation should not be accepted. Persons who have been exempted from measles vaccination for medical, religious, or other reasons should be excluded from affected institutions in the outbreak area until 21 days after the onset of rash in the last case of measles. The recent experience in measles outbreaks shows that almost all persons who are excluded from an outbreak area because they lack documentation of immunity quickly comply with vaccination requirements.

If many cases are occurring among infants <12 months of age, measles vaccination of infants as young as 6 months of age may be undertaken as an outbreak control measure. Monovalent measles vaccine is preferred, but MMR may be administered to children before the first birthday if monovalent measles vaccine is not readily available. In practice, this recommendation may take several months to implement, and several months to halt once the outbreak has ended. Note that children vaccinated before the first birthday should be revaccinated when they are 12–15 months old and again when they are 4–6 years of age.

Control of outbreaks in schools and other institutions. During outbreaks in elementary, junior, and senior high schools, and colleges and other institutions of higher education, as well as other institutions where young adults may have close contact (such as prisons), a program of revaccination with MMR vaccine is recommended in the affected schools or institutions. Recent experience has indicated that measles outbreaks do not occur in schools in which all students are subject to a school requirement for two doses of measles vaccine. In general, voluntary efforts have been much less successful than mandatory two-dose requirements for control of outbreaks. Therefore, public health officials should strongly consider implementing mandatory two-dose requirements for children in affected schools and other institutions. The scope of vaccination effort needed will depend on 1) age-appropriate first- and second-dose coverage with MMR in the community, 2) population density, 3) resources available, and 4) patterns of social contacts within the community. During an outbreak, strong consideration should be given to expanding vaccination efforts to all schools in the community in which students are not already subject to a second-dose requirement, unless second-dose MMR coverage is high in those other schools.

In a school with a measles outbreak, all students and their siblings, and all school personnel born in or after 1957 who cannot provide documentation that they have received two doses of measles-containing vaccine on or after their

first birthday, or cannot provide other evidence of measles immunity (such as serologic testing), should be vaccinated. Persons who cannot readily provide documentation of measles immunity should be vaccinated or excluded from the school or other institution. Persons revaccinated, as well as previously unvaccinated persons receiving their first dose as part of the outbreak control program, may be immediately readmitted to school. Persons who continue to be exempted from or who refuse measles vaccination should be excluded from the school, day care, or other institution until 21 days after the onset of rash in the last case of measles.

Control of outbreaks in medical settings. Persons who work in health care facilities (including volunteers, trainees, nurses, physicians, technicians, receptionists, and other clerical and support staff) are at increased risk of exposure to measles, and all persons who work in such facilities in any capacity should be immune to measles to prevent any potential outbreak. If an outbreak occurs within, or in the areas served by a hospital, clinic, or other medical or nursing facility, all personnel born in or after 1957 (including volunteers, trainees, nurses, physicians, technicians, receptionists, and other clerical and support staff) should receive a dose of MMR vaccine, unless they have documentation of measles immunity. Serologic screening of health-care workers during an outbreak to determine measles immunity is not generally recommended, because arresting measles transmission requires the rapid vaccination of susceptible health-care workers, which can be impeded by the need to screen, wait for results, and then contact and vaccinate the susceptible persons.

Susceptible personnel who have been exposed to measles should be relieved from patient contact and excluded from the facility from the 5th to the 21st day after exposure, regardless of whether they received vaccine or immune globulin after the exposure. Personnel who become ill should be relieved from all patient contact and excluded from the facility for 7 days after they develop rash.

Role of community-wide vaccination efforts in outbreak control. Mass revaccination of entire communities is not of demonstrated benefit in control of measles outbreaks. Such activities may sometimes have to be undertaken because of political or other community demands for “action” and concerns about the acceptability of targeted interventions directed toward selected, high-risk populations, but there is no epidemiological evidence that they are feasible or useful in controlling measles outbreaks.

Quarantine is of limited usefulness in control of measles outbreaks. Imposing quarantine measures for outbreak control is usually both difficult and disruptive to schools and other institutions. Under special circumstances, such as during outbreaks in schools attended by large numbers of persons who refuse vaccination, restriction of an event or other quarantine measures might be warranted. However, such actions are not recommended as a routine measure for control of most outbreaks.

Post-exposure vaccination and use of immunoglobulin to prevent measles in exposed persons. If given within 72 hours of exposure to measles, measles

vaccine may provide some protection. In most settings, post-exposure vaccination is preferable to use of immune globulin. However, immune globulin should be given to pregnant women and immunosuppressed person who are exposed to measles. Immune globulin may be preferred for infants <1 year of age who are household contacts of measles patients because it is likely that they will have been exposed more than 72 hours prior to measles diagnosis in the household member, and they are at highest risk of complications from the disease. ❖

Table 1. Interpretation of measles enzyme immunoassay results*

IgM Result	IgG Result	Previous infection history	Current infection	Comments
+	– or +	not vaccinated, no prior history of measles	recently received 1st dose of measles vaccine	Seroconversion. IgG response depends on timing of specimen collection
+	– or +	not vaccinated, no prior history of measles	wild type measles	Seroconversion. Classic clinical measles. IgG response depends on timing of specimen collection
+	– or +	previously vaccinated, primary vaccine failure	recently received 2nd dose of measles vaccine	Seroconversion. IgG response depends on timing of specimen collection
–	+	previously vaccinated, IgG+	recently received 2nd dose of measles vaccine	IgG level may stay the same or may boost
+	+	previously vaccinated, IgG+	wild type measles	May have few or no symptoms (e.g., no fever or rash).
+	+	recently vaccinated	exposed to wild type measles	Cannot distinguish between vaccine or wild type virus; evaluate on epidemiologic grounds**
–	+	distant history of natural measles	vaccine	IgG level may stay the same or may boost
+ (at least in some patients)	+	distant history of natural measles	wild type measles	May have few or no symptoms.

* These results are those expected when using the capture IgM and indirect IgG enzyme immunoassays and may not apply to different assays due to different techniques and sensitivities/specificities.

** However, in this circumstance, IgM testing will be helpful if negative; it could rule-out wild type measles infection (if negative).

Table 2. Example of line listing for recording data in a measles outbreak investigation

Case ID	Name (Last, First)	Age	Date of birth	Rash onset date	Source of exposure	Blood draw date	IgM result	MMR-1 date	MMR-2 date	Case status
1	Doe, Jane	15 yr		12/31/1999	id #2	1/3/2000		9/16/1985	—	—
2	Smith, Stacey	13 mo		12/16/1999		12/27/1999	+	—	—	lab confirmed
3	Doe, Henry	11 yr		12/26/1999	id #2	1/3/2000		—	—	—
4	Smith, Joe	26 yr		12/30/1999	id #2	1/3/2000		?	—	—

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